CLAIMS

1. A method of centerline determination for a tubular tissue in a medical image data set defined in a data space, comprising:

receiving at least one start point and one end point inside a tubular tissue volume;

automatically determining a path between said points that remains inside said volume;

automatically segmenting said tubular tissue using said path; and

automatically determining a centerline for said tubular tissue from said segmentation,

wherein said receiving, said determining a path and said segmenting, said determining a centerline are all performed on a same data space of said medical image data set.

2. A method according to claim 1, wherein said tubular tissue comprises a body lumen.

3. A method according to claim 1 or claim 2, wherein receiving comprises receiving at most 4 points from a human user.

4. A method according to claim 1 or claim 2, wherein receiving comprises receiving at most 2 points from a human user.

5. A method according to any of claims 1-4, wherein automatically determining a path comprises determining using targeted marching which uses a cost function incorporating both path cost and estimated future path cost.

6. A method accord to claim 5, wherein determining a path comprises propagating a sub-path from each of at least two of said received points until the sub-paths meet.

7. A method accord to claim 5 or claim 6, wherein determining a path comprises propagating a sub-path from one of said received points until it meets another of the received points.

8. A method according to any of claims 5-7, wherein propagating a sub-path comprises selecting a point and selecting a neighbor of the selected point for further consideration responsive to said cost function.

9. A method according to any of claims 5-8, wherein a path cost of a point is a function of a local cost of a point and a path cost of at least one neighbor of the point.

10. A method according to claim 9, wherein a local cost of a point is a function of a probability of the point being inside or outside of the tubular tissue.

11. A method according to claim 9 or claim 10, wherein a path cost is determined by finding at least an approximate solution to an equation including at least one extreme-type function that returns an extreme value of its operands.

12. A method according to claim 11, wherein if a solution is not found, at least one of said extreme-type functions is replaced by a constant value.

13. A method according to claim 12, said extreme-type function to replace is found by a min-max method.

14. A method according to claim 9 or claim 10, said equation includes an approximation of a gradient of the path cost.

15. A method according to any of claims 5-10, wherein a path cost of a point is a function of a probability of the point being inside or outside of the tubular tissue.

16. A method according to claim 10 or claim 15, wherein said probability is determined using a histogram of data point values.

17. A method according to claim 16, comprising updating the histogram when a point is determined to be inside or outside of the tubular tissue.

18. A method according to claim 16, comprising updating the histogram when a point is selected.

19. A method according to claim 18, wherein said histogram is updated with a weight corresponding to a probability of the point being inside the tubular tissue.

20. A method according to any of claims 16-19, comprising generating a local histogram for a part of said vessel.

21. A method according to any of claims 16-20, wherein the histogram comprises an outside histogram for point values that are outside the tubular tissue.

22. A method according to claim 21, wherein the outside histogram includes also points inside the tubular tissue.

23. A method according to any of claims 16-22, wherein the histogram comprises an inside histogram for point values that are inside the tubular tissue.

24. A method according to any of claims 5-23, comprising selecting a target to be used in an estimating of said future cost.

25. A method according to claim 24, wherein said estimating is an underestimating.

26. A method according to claim 24 or claim 25, wherein said estimating is based on an average cost per distance unit.

27. A method according to any of claims 24-26, wherein said estimating is based on an Euclidian distance to said target.

28. A method according to any of claims 24-27, wherein selecting a target comprises selecting from two or more possible targets.

29. A method according to claim 28, wherein selecting a target comprises projecting two vectors, one for each of two potential targets on a vector connecting a current point with a starting point of the current point and selecting a longer projection.

30. A method according to claim 24, wherein selecting a target comprises selecting one of said received points.

31. A method according to any of claims 1-4, wherein automatically determining a path comprises determining using fast marching.

32. A method according to any of claims 1-4, wherein automatically determining a path comprises determining using the A* path finding method.

33. A method according to any of claims 1-4, wherein automatically determining a path comprises determining using Dijkstra's minimal length path finding method.

34. A method according to any of claims 1-33, comprising correcting said determined path.

35. A method according to claim 34, wherein correcting said path comprising interconnecting path segments.

36. A method according to any of claims 1-35, wherein said segmenting uses a marching method for segmentation.

37. A method according to any of claims 1-35, wherein said segmenting uses a contour expansion method.

38. A method according to claim 36, wherein said marching method assigns a value for each point in said tubular tissue.

39. A method according to any of claims 36-38, wherein said marching method is a fast marching method.

40. A method according to any of claims 1-38, wherein said segmenting comprises parametrizing points along said path.

41. A method according to claim 40, comprising propagating said parameterization.

42. A method according to claim 41, wherein said propagated parameterization is used to prevent leakage of said segmentation.

43. A method according to claim 41 or claim 42, wherein said parameterization is propagated substantially parallel to said path.

44. A method according to claim 43, comprising propagating said parameterization to being substantially perpendicular to a path cost gradient associated with said propagation.

45. A method according to claim 42, comprising collecting propagation statistics for different parameterization values.

46. A method according to claim 42, comprising determining a direction of propagation from a propagation of parameterization values.

47. A method according to claim 41, comprising controlling a direction of propagation based on said parameterization.

48. A method according to claim 45, comprising limiting propagation of at least one parameterization value based on said statistics.

49. A method according to claim 48, wherein limiting comprises limiting propagation to relatively locally uniform volume for nearby parameterizations.

50. A method according to any of claims 1-49, wherein said segmenting comprises partitioning said path into portions.

51. A method according to claim 50, comprising defining boundary planes between said portions.

52. A method according to claim 50 or claim 51, wherein said portions overlap by a relatively small amount.

53. A method according to any of claims 50-52, wherein said portions are substantially straight lines.

54. A method according to any of claims 50-53, wherein said partitioning is used to reduce leakage of said segmentation.

55. A method according to any of claims 1-54, wherein said segmenting comprises propagating from said path.

56. A method according to claim 55, wherein said propagating is limited to be relatively perpendicular to said path.

57. A method according to claim 55, wherein said propagating is limited to be relatively locally uniform in a radial direction.

58. A method according to any of claims 55-57, wherein said propagating depends on a local curvature.

59. A method according to claim 58, wherein said local curvature is estimated by counting visited neighbors.

60. A method according to any of claims 1-57, wherein said segmenting comprises segmenting using a histogram of data values to determine a probability of a point being inside the tubular tissue.

61. A method according to claim 60, wherein different parts along said path have different histograms.

62. A method according to claim 61, wherein said histograms are created to vary smoothly between said parts.

63. A method according to claim 61 or claim 62, wherein a noise level in at least one of said histograms is reduced using a global histogram.

64. A method according to any of claims 60-63, comprising repeatedly updating said histograms during said segmenting.

65. A method according to any of claims 1-64, comprising cleaning the segmentation.

66. A method according to any of claims 1-65, wherein determining a centerline comprises generating a distance map of said tubular tissue, of distances from an outer boundary of said tubular tissue, inwards.

67. A method according to claim 66, wherein generating a distance map comprises using morphological skeletonization on said segmentation.

68. A method according to claim 66, wherein determining a distance map comprises using fast marching on said segmentation.

69. A method according to any of claims 66-68, wherein determining a centerline comprises finding a path in said distance map.

70. A method according to claim 69, wherein finding a path for said centerline comprises targeted marching from at least one end of said segmentation.

71. A method according to claim 70, wherein said targeted marching for finding a path comprises taking a local curvature into account.

72. A method according to any of claims 1-71, wherein said data set is three dimensional.

73. A method of segmenting an organ in a medical image data set, comprising:

dividing said data set into portions; and

using a different probability histogram in each of at least two of said portions for determining if a point belongs in the segmentation.

74. A method according to claim 73, comprising smoothing at least two histograms, for two neighboring portions.

75. A method according to claim 74, wherein said smoothing comprises registering a plurality of points in both of said neighboring histograms.

76. A method according to any of claims 73-75, comprising correcting said different histograms using a global histogram that encompasses at least two of said different histograms.

77. A method of segmenting an organ in a medical image data set, comprising:

defining a plurality of partially overlapping portions in said data set, which portions cover at least one object of interest;

separately segmenting each of said portions; and

combining said segmentations to yield a single segmentation of said at least one object.

78. A method according to claim 77, wherein said portions are selected to divide a tubular organ into substantially straight sections.

79. A method of segmenting an organ in a medical image data set, comprising:

propagating a segmentation in said data set; and

applying a curvature limitation to said propagation.

80. A method according to claim 79, wherein applying a curvature limitation comprises counting visited neighbors.

81. A method of propagating parameterization in a medical image data set, comprising:

providing an initial parameterization in said data set along at least one line;

propagating a parameterization from said line, wherein said propagation is limited to being substantially parallel to said at least one line.

82. A method according to claim 81, comprising propagating said parameterization to have a gradient which is substantially perpendicular to a gradient of a path cost associated with said propagation.

83. A method according to claim 81 or claim 82, comprising limiting an angle between (a) a spatial vector defined between a starting point of the parameterization along said line and ending at a current point of propagation of parameterization and (b) said path, to being close to perpendicular.

84. a method according to claim 83, wherein said limiting comprises reducing leakage of a segmentation by said limiting.

85. A method according to any of claims 81-83, wherein said medical image data set is a three-dimensional data set.

86. A method of centerline finding in a distance map, comprising:

providing a distance map of an organ having a centerline;

determining a desired tradeoff between curvature and (a) local curvature of a path and (b) remaining near said centerline ;and

finding a path in said map while applying limitations of (a) local curvature of the path and (b) remaining near said centerline,

wherein said finding a path comprises applying said trade-off in a manner which is uniform at points along a path in organs having cross-sectional areas different by more than 50%.

87. A method according to claim 86, wherein said limitations are applied as part of a targeted marching method in which a path is found by propagation of wave front using a cost function which depends on both a local cost and an estimated cost to target.

88. A method according to claim 87, wherein said trade-off is applied to at least two points in a same organ.

89. A method according to claim 87, wherein said trade-off is applied to two different organs in a same data set.

90. A method according to any of claims 86-89, wherein applying said tradeoff comprises using a formula for trading off which includes an exponent and normalization of organ diameter.

91. A method according to any of claims 86-90, wherein said tradeoff is uniform on different parts of a cross-section of said organ over a range of at least 50% of said cross-section, such that same movement has a similar effect on curvature.

92. A method of centerline determination for a body tubular tissue in a medical data set, comprising:

providing a data set including a tubular tissue having n points in a three-dimensional medical dataset; and

finding a path in said data set in O(nlogn) time of scalar calculation steps.

93. A method according to claim 92, wherein said path is found using no more than O(n) memory units.

94. A method of centerline determination for a body tubular tissue in a medical data set, comprising:

providing a data set including a tubular tissue having n points in a three-dimensional medical dataset; and

finding a path in said data set using no more than O(n) memory units.